NASA / FAA eVTOL Crashworthiness Virtual Meeting

April 7th 2020

Justin Littell Ph.D.
NASA Langley Research Center
Structural Dynamics Branch
Why another eVTOL workshop/meeting?

- Intended to be specific to occupant protection and vehicle crashworthiness with specific application to eVTOL vehicle designs
  - Other system have their respective conferences and/or working groups
- Other similar have addressed crashworthiness/occupant safety
  - ASTM F44 eVTOL workshop / UAM working group
  - VFS Defining challenges
  - VFS Transformative Vertical Flight
- Today will be mainly an introduction to familiarize the UAM community to the concepts of vehicle crashworthiness from both a historical perspective but also how it can apply to eVTOL vehicle designs.
- A full day in-person workshop is still being planned at NASA LaRC tentatively Fall 2020. See https://nari.arc.nasa.gov/crashworthiness for details
Agenda – Webinar April 7th, 2020

• Welcome – Justin Littell / NASA
• Introduce the concept of crashworthiness from a historical perspective – Joseph Pellettiere / FAA
• Introduce a series of case studies that capture crashworthiness themes – Amanda Taylor / FAA
• Introduce potential paths toward certification regarding crashworthiness – Robert Stegeman / FAA

• Virtual meeting expected to last 1-1.5 hours.
Meeting Etiquette

• Stay on mute so that crosstalk/feedback/background noise is minimized. Speakers will be only ones talking.

• Questions can be submitted through the comment section of the zoom meeting - please write down your question in the comment section. **Questions will not be answered during the presentations**, but collected/recorded and addressed at the in-person workshop later this year.

• Other specific questions can be directed toward
  – Justin Littell – Justin.D.Littell@nasa.gov
  – Joseph Pellettiere – Joseph.Pellettiere@faa.gov
Introduction to Crashworthiness

Presented to: UAM Crashworthiness Workshop

By:
Joseph A. Pellettiere, Chief
Scientific and Technical Advisor for Crash Dynamics

Amanda Taylor, Biodynamic Research Engineer, Civil Aerospace Medical Institute

Bob Stegeman
Small Airplane Standards Branch

Date: April 2020
Agenda

- Survivable crash
- What is crashworthiness
- Regulation history
- Physics of Impact
- Examples
- Current eVtol certification approach
- Future workshop
Miscellaneous Accident Facts

Thermal/fire injuries account for approximately 50% of fatalities

Impact injuries (trauma) account for approximately 50% of fatalities

Vast majority of accidents occur during the takeoff and landing phases

Takeoffs result in more severe fire accidents
Definition of a Survivable Accident

Survivable Accident: Survivable volume, restrained occupants, acceptable acceleration limits (injuries due to trauma not thermal/fire).

Most accidents are survivable.
## Possible Crash Scenarios

<table>
<thead>
<tr>
<th>CANDIDATE CRASH SCENARIO</th>
<th>IMPACT CONDITIONS</th>
<th>ACCIDENT TYPE</th>
<th>TERRAIN</th>
<th>HAZARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUND-TO-GROUND, OVERRUN</td>
<td>LOW SINK SPEED</td>
<td>TAKEOFF ABORT</td>
<td>RUNWAY</td>
<td>DITCH</td>
</tr>
<tr>
<td></td>
<td>LOW FORWARD VELOCITY</td>
<td>LANDING OVERRUN</td>
<td>HARD GROUND</td>
<td>MOUND</td>
</tr>
<tr>
<td></td>
<td>SYM. A/P ATTITUDE</td>
<td></td>
<td></td>
<td>SLOPE</td>
</tr>
<tr>
<td></td>
<td>Gears Extended</td>
<td></td>
<td></td>
<td>SLAB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LIGHT STANCHION</td>
</tr>
<tr>
<td>AIR-TO-GROUND HARD LANDING</td>
<td>HIGH SINK SPEED AND</td>
<td>HARD LANDING</td>
<td>RUNWAY</td>
<td>NONE</td>
</tr>
<tr>
<td></td>
<td>LANDING VELOCITY</td>
<td>UNDERSHOOT</td>
<td>HARD GROUND</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYM. A/P ATTITUDE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gears Extended</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIR-TO-GROUND IMPACT</td>
<td>HIGH SINK SPEED AND</td>
<td>UNCONT/CONT</td>
<td>WOODED</td>
<td>TREES</td>
</tr>
<tr>
<td></td>
<td>LANDING VELOCITY</td>
<td>GRD COLLISION</td>
<td></td>
<td>SLOPES</td>
</tr>
<tr>
<td></td>
<td>UNSYM. A/P ATTITUDE</td>
<td>STALL</td>
<td>HILLY</td>
<td>BLDGS</td>
</tr>
<tr>
<td></td>
<td>Gears Extended/RET</td>
<td>UNDERSHOOT</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Survivable Accidents Occur

Figure 8. Number of Fatalities—All Accidents and Survivable Accidents—World Fleet
Survivable Crash Events

- Metal airframe with crushable space
  - Absorb primary impact energy
- Current seat designs
  - Protect occupant
  - Minimize secondary impact
- Cabin interior
  - Minimize secondary impact such as luggage bins
- Provide adequate exits
  - Need structural integrity

July 2013 – Asiana Flt 214
(777 - 3 fatal, 49 of 187 serious inj/307)

February 2009 – Turkish Flt 1951
(737-800 9 fatal, 25 severe inj/125)
Crashworthiness needs to be a primary design consideration instead of a last resort

Instead of focus on seat, need multiple features that create a system for occupant protection

Must consider certification cost verses safety benefits to get the best overall system

Level of precision and confidence in certification requirements directly related to –
  - Risk allowances
  - Cost
  - Safety continuum

One size doesn’t actually fit all
What is Crashworthiness?

Crashworthiness is the ability of a structure to protect its occupants during an impact.

A crashworthy aircraft/rotorcraft is capable of:

- Limiting the loads transmitted to the occupants to survivable and/or non-injurious, humanly-tolerable levels (for a “survivable” impact).
- Providing a protective cabin surrounding the occupants.
- Providing a secure tie down of the occupants through the use of seats, restraint systems, seat track, and floor.
- Eliminating post-crash fire hazards and providing for emergency egress.
- Mitigating head strike potential by using pre-tensioned restraint systems or cockpit air bags.
Aircraft Crashworthiness
The Beginning

• Hugh DeHaven – considered by many to be the father of aircraft crashworthiness, developed the first systematic statement of the principles of crashworthiness.

• Packaging principles of light aircraft design - 1952
DeHaven’s Four Principles

• The package should not open up and spill its contents, and should not collapse under expected conditions of force.

• The packaging structures which shield the inner container must not be made of brittle or frail materials; they should resist force by yielding and absorbing energy.

• Articles contained in the package should be held and immobilized. This interior packaging is an extremely important part of the overall design, for it prevents movement and the resultant damage from impact against the inside of the package itself.

• The means for holding an object inside a shipping container must transmit the forces applied to the container to the strongest parts of the contained objects.
Current Crashworthiness Philosophy

CREEP

Container – The fuselage's resistance to structural collapse, and the survivable volume in occupied spaces.

Restraint – The ability of seat belts and seats to help passengers survive the sudden force of deceleration during impact.

Environment – The cabin interior design must minimize the potential for injury during a crash (i.e. overhead bins do not collapse onto passengers).

Energy Absorption – The fuselage should provide energy absorption through controlled deformation.

Postcrash factors – Occupants must be able to perform post crash actions (i.e. evacuation).
Container

Maintain Survivable Volume
Seat Restraint Systems

Dynamic requirements:

14 CFR 23.562, 25.562, 27.562, 29.562

Lumbar load limits
Head injury criteria
Seat belt load limits
Environment

Protect against secondary impacts
Energy Management

Energy absorbing structures

Landing gear

Fuselage
- Frames
- Keel beams
- Stanchions
- Floor beams

Seats
- Energy absorbing – passive design
- Stroking – active design
- Energy absorbing seat pan design

Nonstructural
- Inflatable
- Parachute
Postcrash

Evacuation
Exits
Aisle way lighting
Slides
Life rafts
Elements of Crashworthy Aircraft System Design

- Airframe structure
  - Strength
  - Impact attenuation
- Aircraft seats
  - Strength
  - Energy absorbing
  - Occupant injury criteria

- Interior furnishings
  - Overhead bins
- Post crash fire
  - Fuel containment
  - CRFS
- Emergency evacuation
  - Availability of exits

[Diagram showing elements of airframe structure, aircraft seats, interior furnishings, and post-crash fire containment.]
History of the Standards

• Original requirements focused on seat and restraint system strength

• Static test requirements were essentially the same since 1958
  – Title 14, Section 561 of Parts 23,25,27 and 29: Emergency Landing Conditions, General.
  – TSO C39b: Aircraft Seats and Berths (cites NAS 809)
  – TSO C22f: Safety Belts (cites NAS 802)
History of the Standards

Loads applied slowly with wooden blocks in multiple directions. Does not apply forces in the same way an actual occupant would.

Forward Static Test

Lateral Static
History of the Standards

Dynamic testing revealed serious problems with seats that met the static test standards
Development of Standards

• The General Aviation Safety Panel (GASP) was Instrumental in Formulating Dynamic Performance Standards

• Represented a broad constituency from the General Aviation Community

• Objectives
  – Analyze Results of Existing Crash Dynamics Research
  – Develop Crash Dynamics Design Standards

A 1979 photo by Brian Smith of the wreck of Cessna 172 N734YH at the end of Maguire's Runway 18
Development of Standards

• The Development and Application of Crash Dynamics Technology Fostered the Dynamic Performance Standards

• US Army’s Aircraft Crash Survival Design Guide
  – Hughes AH-64A Apache
  – Sikorsky UH-60A Blackhawk

• FAA/NASA Crash Dynamics Research
Development of Standards

New standards for small aircraft were developed based on full-scale fuselage impact tests.

- vertical drop tests
- combined horizontal / vertical impact tests
Development of Standards

Example Time Histories

NORMAL CABIN FLOOR PULSES

DECELERATION
G UNITS

TIME - SEC

NASA G.A. AIRPLANES TEST DATA

ANALYTICAL PULSE SHAPES

TRIANGULAR

HALF SINE

SQUARE WAVE

VELOCITY CHANGE AT IMPACT - M/SEC

Example Time Histories

NORMAL CABIN FLOOR PULSES

DECELERATION
G UNITS

TIME - SEC

NASA G.A. AIRPLANES TEST DATA

ANALYTICAL PULSE SHAPES

TRIANGULAR

HALF SINE

SQUARE WAVE

VELOCITY CHANGE AT IMPACT - M/SEC
Development of Standards
Impact Pulse Duration as a Function of Impact Attitude

\[ \Delta t = c(1 - \delta)(e + 4)^2 + 0.052 \]

NASA/FAA IMPACT TESTS
(11 TESTS)
(9 TESTS)

VERTICAL VELOCITY CHANGE - FT/SEC
GASP Established a Pass/Fail Performance Criteria

- Performance Criteria Relates Selected Measured Dynamic Test Parameters to Injury Criteria
- Performance Criteria Evaluates the Seat/Restraint System’s Potential for Preventing or Minimizing Injuries from:
  - Primary Impacts
  - Secondary Impacts
  - Occupant Skeletal Loads
Development of Standards

• New standards for rotorcraft were based primarily on analysis of accident data.
• Large data base available from the military
Development of Standards

Crashworthiness
April 2020

LONGITUDINAL IMPACT VELOCITY - FT/SEC

VERTICAL IMPACT VELOCITY - FT/SEC

CIVIL
95TH% ALL ACCIDENTS
95TH% SURVIVABLE

U.S. CIVILIAN HELICOPTERS
U.S. ARMY HELICOPTERS, 95TH% CURRENT DESIGN REQUIREMENTS
U.S. ARMY OH-58A, 95TH% SURVIVABLE
U.S. NAVY HELICOPTERS 95TH% SURVIVABLE
LAND
WATER

TO 140 FT/SEC
Development of Standards

Frequency Of Major And Fatal Injuries To Each Body Region As Percentages Of Total Major And Fatal Injuries In Survivable Accidents
## Seat Safety Standards

### Test-1 Condition

<table>
<thead>
<tr>
<th>Combined Vertical Horizontal Orientation</th>
<th>Small Airplanes (Part 23)</th>
<th>Transport (Part 25)</th>
<th>Rotorcraft (Part 27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gpk (gs)</td>
<td>Pilot: 19</td>
<td>Passenger: 15</td>
<td>14</td>
</tr>
<tr>
<td>Impact Velocity (ft/s)</td>
<td>31</td>
<td>31</td>
<td>35</td>
</tr>
<tr>
<td>Onset Time (Tpk)</td>
<td>0.05</td>
<td>0.06</td>
<td>0.08</td>
</tr>
</tbody>
</table>

### Test-2 Condition

<table>
<thead>
<tr>
<th>Horizontal 10° Yaw Orientation</th>
<th>Small Airplanes (Part 23)</th>
<th>Transport (Part 25)</th>
<th>Rotorcraft (Part 27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gpk (gs)</td>
<td>Pilot: 26</td>
<td>Passenger: 21</td>
<td>16</td>
</tr>
<tr>
<td>Impact Velocity (ft/s)</td>
<td>42</td>
<td>42</td>
<td>44</td>
</tr>
<tr>
<td>Onset Time (Tpk)</td>
<td>0.06</td>
<td>0.08</td>
<td>0.09</td>
</tr>
</tbody>
</table>
Seat Safety Standards

- Dynamic test requirements were adopted in 1988 for Parts 23 and 25, and 1989 for Parts 27 and 29.
- These requirements were originally applicable to aircraft designed after the effective date, not to ones already in design or production.
- The requirements have also been partially implemented on some new derivative aircraft.
Historical Summary

- Current transport standards were quickly implemented by industry
- Survivability with conventional designs has shown good crashworthiness performance
- General aviation and rotorcraft are lagging due to adoption rate
- Newly designed aircraft can start anew and maintain the safety performance
Current Standards and Case Studies

eVTOL Crashworthiness Workshop

By: Amanda Taylor
Biomedical Research Engineer
Civil Aerospace Medical Institute

Date: April 7, 2020
The Physics of Impact

Large horizontal velocity change over a relatively long period of time
The Physics of Impact

Small vertical velocity change and a moderate horizontal velocity change over a short time period
The Physics of Impact

Small vertical velocity change over a very short time period
## Integral Seats – Test 1

<table>
<thead>
<tr>
<th>Combined Vertical Horizontal Orientation</th>
<th>Rotorcraft (Part 27/29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak G (gs)</td>
<td>30</td>
</tr>
<tr>
<td>Impact Velocity (ft/s)</td>
<td>30</td>
</tr>
<tr>
<td>Onset Time</td>
<td>30 ms</td>
</tr>
</tbody>
</table>
## Injury/Pass-Fail Criteria

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Injury Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Injury Criteria (HIC)</td>
<td>1000</td>
</tr>
<tr>
<td>Shoulder Harness loads</td>
<td>1750 lb. (single) 2000 lb. (dual)</td>
</tr>
<tr>
<td>Lumbar Load Fz</td>
<td>1500 lb.</td>
</tr>
<tr>
<td>Femur Load (axial)*</td>
<td>2250 lb.</td>
</tr>
</tbody>
</table>

Specified in Part 23.562, 25.562, 27.562, and 29.562
Measured for Part 572 Subpart B (Hybrid II)
* (part 25 only)
Case Study – Unintended Use Fly Nyon

- ERA18MA099
- March 11, 2018
- 5 Fatal
- 1 Minor

AS 350 B3E
Case Study Fly Nyon
Case Study – Post Crash Fire

• CHI15MA290
• July 3, 2015
• 1 Fatal
• 2 Serious

AS 350 B3E
Case Study – Fully Crashworthy Aircraft

• ERA16LA124
• 3/05/2016
• 2 None

Cirrus SR22
Case Study – Fully Crashworthy Aircraft

- CHI06FA245
- 8/28/2006
- 1 Fatal
- 3 Serious

Cirrus SR22
Case Study – Child Restraints

- CEN17FA067
- January 4, 2017
- 1 Fatal
- 1 Serious
- 1 None

Experimental Bede BD-4
Case Study – Child Restraints
Crashworthiness Innovations

EMAS – Engineered Material Arresting System

Deployable Energy Absorber
Possible eVTol Certification Approach

Presented to: UAM Crashworthiness Workshop

By: Bob Stegeman
    Small Airplane Standards Branch

Date: April 2020
EVTOL Certification-First Steps

• Define the aircraft configuration
• Define the aircraft utilization
• Determine standards staff based upon configuration
• These aircraft don’t typically fit into the normal certification holes and require coordination for cert basis
• Certification basis made more difficult without fixed design
EVTOL Certification-Regulatory Framework

- Framework for Certification has changed in past couple of years for part 23
  - Performance based-broader rules
  - Prescriptive requirements in industry standards
- Part 27 has not completed this change yet
- Old prescriptive methods are still utilized in both 23/27
- Hybridization of these methods for cert basis takes more time
- Much of crashworthiness not changed much since 1980s
EVTOL Certification - Regulations + Vehicle

• Define how vehicle operates/flies/ crashes
• How does it crash, based upon how it flies considering loss of power, thrust
  – Vtol-has transient phase to horizontal or is purely vertical thrust-will drop like helo
  – Fixed wing/wingborne lift flight(can land horizontally)-will glide in like airplane

• Determine cert basis
  – Primarily part 23
  – Primarily part 27
  – Combination part 23/27 hybrid
EVTOL Certification-Methods of Compliance

After cert basis determined……

How do we demonstrate crashworthiness?

• Test or analysis based upon test…. there will be testing…..

• Some form of traditional dynamic/static option

• Longer/More Advanced/Likely Safer/But…More Expensive Paths
  – Automotive path of full vehicle crash response/dummy restraint
  – Potentially extensive modelling that will likely require substantiation via large scale test

• New avenues will be more of a challenge as vehicle type/operations certification is not stable

• Traditionally, Certification moves ahead incrementally
EVTOL Certification-Current Example Static Loads

- Conventional wisdom and current state of the art for a s/vtol plane with wingborne cruise

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Occupant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward</td>
<td>9.0g</td>
<td>9.0g</td>
<td>16g</td>
<td></td>
</tr>
<tr>
<td>Rearward</td>
<td>-</td>
<td>-</td>
<td>1.5g</td>
<td></td>
</tr>
<tr>
<td>Upward</td>
<td>3.0g</td>
<td>3.0g</td>
<td>4g</td>
<td></td>
</tr>
<tr>
<td>Downward</td>
<td>6.0g</td>
<td>6.0g</td>
<td>20g after intended displacement of seat device</td>
<td></td>
</tr>
<tr>
<td>Sideward</td>
<td>1.5g</td>
<td>1.5g</td>
<td>8g</td>
<td></td>
</tr>
<tr>
<td>Occupant weight</td>
<td>190 pounds</td>
<td>170 pounds*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static items of Mass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward</td>
<td>18.0g</td>
<td>18.0g</td>
<td>12g</td>
<td></td>
</tr>
<tr>
<td>Rearward</td>
<td>-</td>
<td>-</td>
<td>1.5g</td>
<td></td>
</tr>
<tr>
<td>Upward</td>
<td>3.0g</td>
<td>3.0g</td>
<td>1.5g</td>
<td></td>
</tr>
<tr>
<td>Downward</td>
<td>-</td>
<td>-</td>
<td>12g</td>
<td></td>
</tr>
<tr>
<td>Sideward</td>
<td>4.5g</td>
<td>4.5g</td>
<td>6g</td>
<td></td>
</tr>
<tr>
<td>Retractable Gear</td>
<td>3g</td>
<td>3g</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Ultimate inertia force</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*170 pounds is used as 190 pounds is traditionally used to accommodate parachute on utility and acrobat aircraft.
**EVTOL Certification-Current Example Dynamic Loads**

- Conventional wisdom and current state of the art for a s/vtol plane with wingborne cruise

<table>
<thead>
<tr>
<th>Dynamic Occupant</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; test (combined fwd/down) 1&lt;sup&gt;st&lt;/sup&gt; row</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; test (combined fwd/down) Other rows</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; test (FWD) with floor warpage 1&lt;sup&gt;st&lt;/sup&gt; row</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; test (FWD) with floor warpage Other rows</th>
<th>ATD weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19g, $\Delta$ velocity = 31 ft/sec, 0.05 sec rise time</td>
<td>15g, $\Delta$ velocity = 31 ft/sec, 0.06 sec rise time</td>
<td>26g, $\Delta$ velocity = 42 ft/sec, 0.05 sec rise time</td>
<td>21g, $\Delta$ velocity = 42 ft/sec, 0.06 sec rise time</td>
<td>170 pounds</td>
</tr>
<tr>
<td></td>
<td>19g, $\Delta$ velocity = 31 ft/sec, 0.05 sec rise time</td>
<td>15g, $\Delta$ velocity = 31 ft/sec, 0.06 sec rise time</td>
<td>26g, $\Delta$ velocity = 42 ft/sec, 0.05 sec rise time</td>
<td>21g, $\Delta$ velocity = 42 ft/sec, 0.06 sec rise time</td>
<td>170 pounds</td>
</tr>
<tr>
<td></td>
<td>30g, $\Delta$ velocity = 30 ft/sec, 0.031 sec rise time</td>
<td>30g, $\Delta$ velocity = 30 ft/sec, 0.031 sec rise time</td>
<td>18.4g, $\Delta$ velocity = 42 ft/sec, 0.071 sec rise time</td>
<td>Same as above</td>
<td>170 pounds</td>
</tr>
</tbody>
</table>

*Note: Dynamic loads are presented for various test scenarios, including conventional and advanced configurations.*
EVTOL Certification-Best Practices

Advantageous to build crashworthiness features into airframe design

- Crushable, energy absorbing airframe
- More-rigid passenger cabin structure
- Anti plowing bulkheads/features
- Solid restraint/seat attachments to airframe, but can gimbal and stay attached in crash
- Consider headstrike/flail envelope in cabin avoid rigid, sharp features
- Restrain items of Mass/batteries/powerplants/cargo
- Ensure egress capability features after crash/deformation
- Minimize post crash fire hazards
# Agenda for in-person workshop, Fall 2020

https://nari.arc.nasa.gov/crashworthiness

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 AM</td>
<td>Coffee</td>
</tr>
<tr>
<td>8:30 AM</td>
<td>NASA LaRC Justin Littell Welcome and Introduction to the Workshop</td>
</tr>
<tr>
<td>8:40 AM</td>
<td>NASA LaRC Susan Gorton NASA RVLT Project Overview</td>
</tr>
<tr>
<td>8:50 AM</td>
<td>VFS Mike Hirschberg The Electric VTOL Revolution</td>
</tr>
<tr>
<td>9:00 AM</td>
<td>FAA Joseph Pellettiere Historical Basis for Crashworthiness and Occupant Safety</td>
</tr>
<tr>
<td>9:30 AM</td>
<td>FAA CAMI Amanda Taylor Current Seat Testing and Accident Case Studies</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>NASA LaRC Jacob Putnam Certification by analysis - NASA F28 case study</td>
</tr>
<tr>
<td>10:20 AM</td>
<td>Break</td>
</tr>
<tr>
<td>10:45 AM</td>
<td>NIAR Gerardo Oliveras How simulation can aid in crashworthy design</td>
</tr>
<tr>
<td>11:15 AM</td>
<td>NASA LaRC Justin Littell NASA Crashworthiness research as basis for regulations</td>
</tr>
<tr>
<td>11:30 AM</td>
<td>NAVAIR Lindley Bark DoD/NAVY Crashworthiness Approach</td>
</tr>
<tr>
<td>11:50 AM</td>
<td>USAARL Joseph McEntire Army Crashworthiness</td>
</tr>
<tr>
<td>12:10 PM</td>
<td>EASA Aiko Duehne EASA VTOL SC</td>
</tr>
<tr>
<td>12:30 PM</td>
<td>Lunch</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>GAMA Lowell Foster The Need for Alternative Crashworthiness Approaches for eVTOL</td>
</tr>
<tr>
<td>1:30 PM</td>
<td>ASTM Eric Nottorf ASTM F44 as Means of Compliance for Part 23</td>
</tr>
<tr>
<td>2:00 PM</td>
<td>Uber Ryan Naru Specifications of UAM Operations</td>
</tr>
<tr>
<td>2:30 PM</td>
<td>FAA AIR Bob Stegeman FAA Application of Crashworthiness Regulations for EVTOLS/UAM vehicles Part 1</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>FAA AIR Bob Stegeman FAA Application of Crashworthiness Regulations for EVTOLS/UAM vehicles Part 2</td>
</tr>
<tr>
<td>3:30 PM</td>
<td>Open discussion</td>
</tr>
<tr>
<td>4:00 PM</td>
<td>Open discussion</td>
</tr>
<tr>
<td>4:30 PM</td>
<td>NASA LaRC Martin Annett LandIR Tour</td>
</tr>
<tr>
<td>5:00 PM</td>
<td>ADJOURN</td>
</tr>
</tbody>
</table>